RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary GCE

PHYSICS A — 2822

Electrons and Photons

Monday **12 JANUARY 2004** Morning 1 hour

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**7**	
2	**9**	
3	**6**	
4	**5**	
5	**16**	
6	**17**	
TOTAL	**60**	

This question paper consists of 12 printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\frac{I}{I_0}\right)$

[Turn over

Answer **all** the questions.

1 **(a)** Explain what is meant by *electric current*.

.... [1]

(b) The SI unit of electric charge is the coulomb. Define the *coulomb*.

....

.... [1]

(c) Fig. 1.1 shows two strips of aluminium foil connected to a d.c. supply.

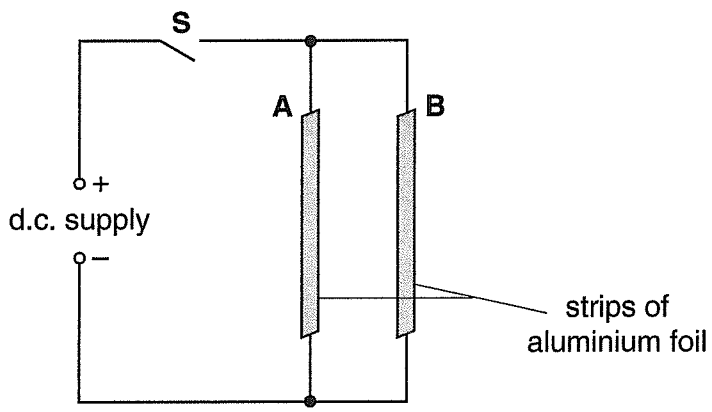

Fig. 1.1

The switch **S** is closed.

(i) The charge flow past a particular point in one of the aluminium strips is 340 C in a time of 50 s. Calculate the current in this aluminium strip.

current = ... A [2]

(ii) 1 There is a force between the two aluminium strips when the switch is closed. State why each of the aluminium strips experiences a force.

....

....

2 Name the rule that may be used to determine the direction of the force on a current-carrying wire in an electric motor.

....

3 State the direction of the force experienced by the aluminium strip **B**.

.... [3]

[Total: 7]

2 **(a)** State Ohm's law.

....

....

.... [2]

(b) The I/V characteristic for a particular component is shown in Fig. 2.1.

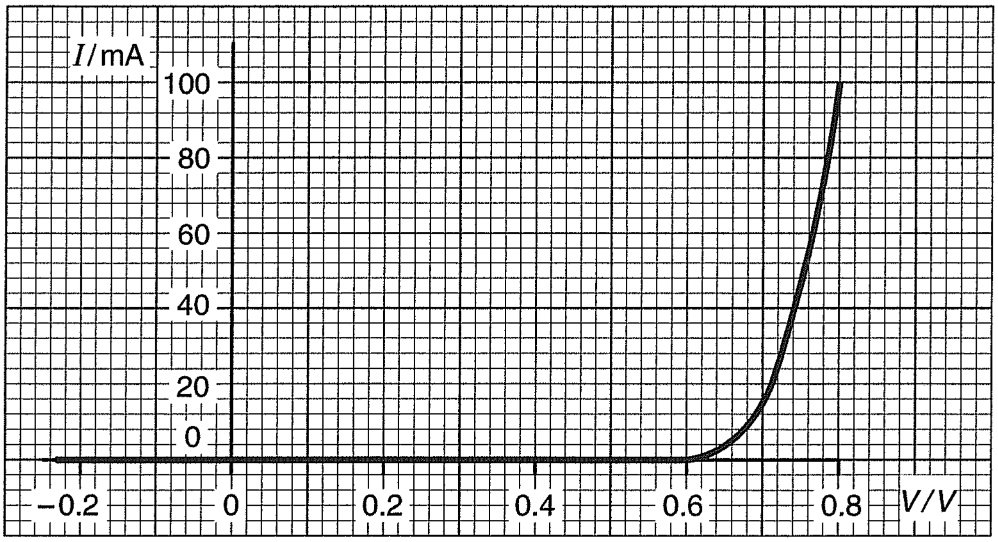

Fig. 2.1

(i) Name the component with the I/V characteristic shown in Fig. 2.1.

.... [1]

(ii) In this question, one mark is available for the quality of written communication.

Describe, making reference to Fig. 2.1, how the resistance of the component depends on the potential difference V across it. You are advised to show any calculations.

....

....

....

....

....

....

....

....

.... [5]

Quality of Written Communication [1]

[Total: 9]

For Examiner's Use

3 **(a)** State Kirchhoff's first law.

....

....

.... [2]

(b) Fig. 3.1 shows part of an electrical circuit.

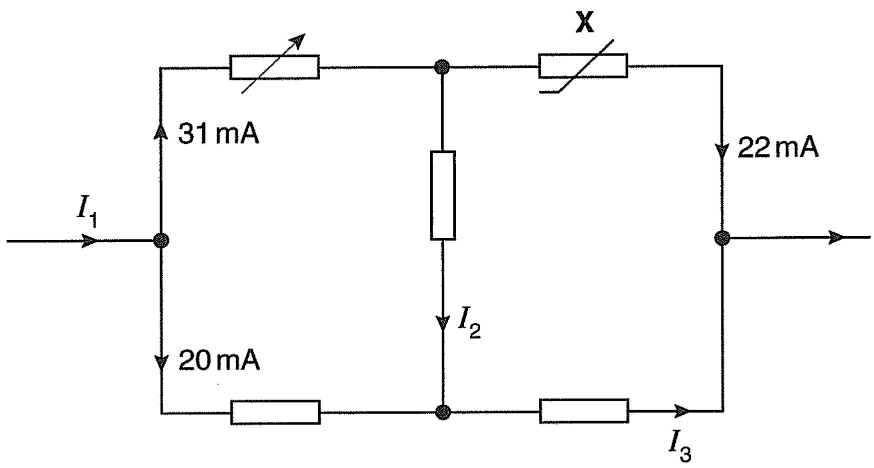

Fig. 3.1

(i) Name the component marked **X**.

.... [1]

(ii) Determine the magnitude of the currents I_1, I_2 and I_3.

I_1 = ... mA

I_2 = ... mA

I_3 = ... mA

[3]

[Total: 6]

4 Fig. 4.1 shows an electrical circuit.

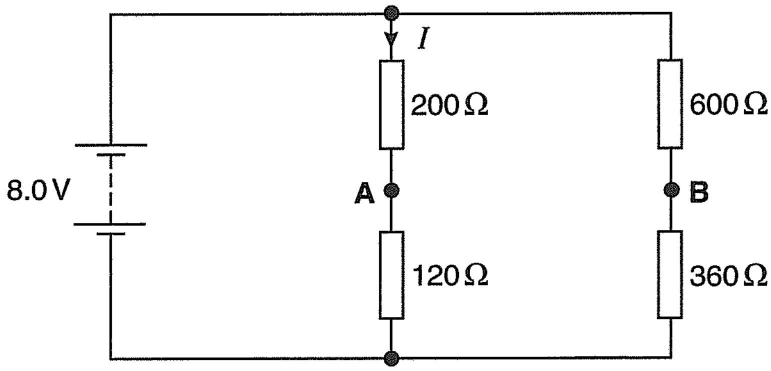

Fig. 4.1

The battery has negligible internal resistance.

(a) Show that the current I is 25 mA.

[2]

(b) Calculate the potential difference (p.d.) across the resistor of resistance 120 Ω.

p.d. = ... V [1]

(c) Explain why a voltmeter connected between points **A** and **B** will read 0 V.

....

....

.... [2]

[Total: 5]

For Examiner's Use

5 Fig. 5.1 shows a plan view of an electrical circuit that includes a flat circular coil.

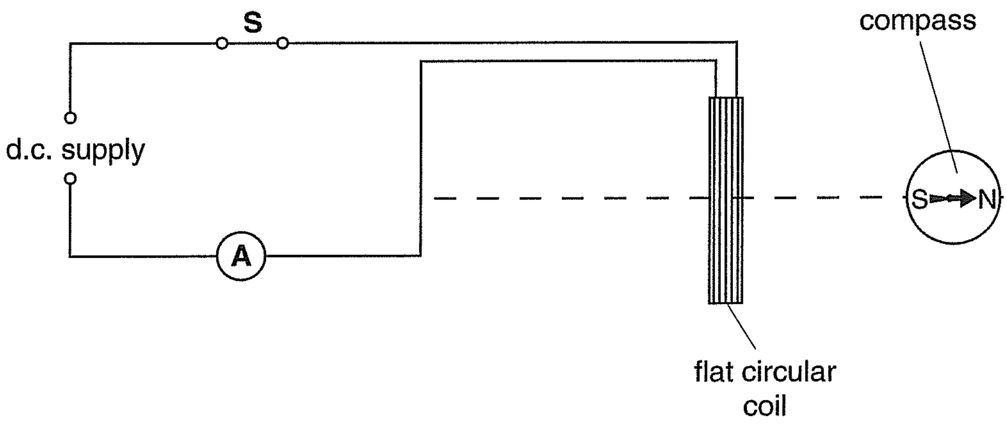

Fig. 5.1

(a) A small compass is placed close to the coil along its axis. When the switch **S** is closed, the compass needle deflects so that it points in the direction shown in Fig. 5.1.

On Fig. 5.1, draw the magnetic field pattern for the flat circular coil. [2]

(b) The coil is made from insulated wire of cross-sectional area $8.4 \times 10^{-7}\,m^2$. At room temperature, the material of the wire has resistivity $4.9 \times 10^{-7}\,\Omega\,m$. The coil consists of 20 turns and has a mean radius 2.8 cm.

(i) Show that the total length of the wire is 3.5 m.

[1]

(ii) Calculate the resistance of the coil.

resistance = ... Ω [3]

For Examiner's Use

(c) Fig. 5.2 shows the variation with time t of the current I in the circuit after the switch **S** has been closed.

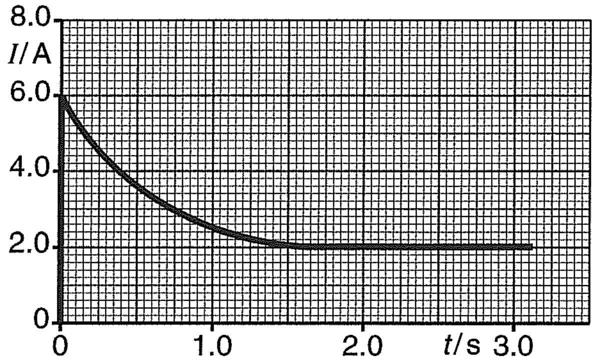

Fig. 5.2

(i) Calculate the potential difference (p.d.) across the coil immediately after the switch **S** is closed.

p.d. = ... V [2]

(ii) Calculate the power dissipated by the coil immediately after the switch **S** is closed.

power = ... unit .... [3]

(iii) In this question, one mark is available for the quality of written communication.

Explain why the current changes as shown in Fig. 5.2.

....

....

....

....

....

....

....

....

....

.... [4]

Quality of Written Communication [1]

[Total: 16]

For Examiner's Use

6 **(a)** State what property of electromagnetic radiation is demonstrated by the photoelectric effect.

.... [1]

(b) Define each of the following terms

(i) photon

....

.... [1]

(ii) threshold frequency.

....

.... [1]

(c) An argon-laser emits electromagnetic radiation of wavelength 5.1×10^{-7} m. The radiation is directed onto the surface of a caesium plate. The work function energy for caesium is 1.9 eV.

(i) Name the region of the electromagnetic radiation emitted by the laser.

.... [1]

(ii) Show that the work function energy of caesium is 3.0×10^{-19} J.

[1]

(iii) Calculate

1 the energy of a single photon

energy = ... J [2]

2 the maximum kinetic energy of an electron emitted from the surface of caesium.

kinetic energy = ... J [3]

For Examiner's Use

(iv) State and explain what change, if any, occurs to the maximum kinetic energy of an emitted electron if the intensity of the laser light is reduced.

....

....

....

.... [2]

(v) The power of the laser beam is 80 mW. Calculate the number of electrons emitted per second from the caesium plate assuming that only 7.0% of the incident photons interact with the surface electrons.

number = ... s^{-1} [2]

(d) Moving electrons have a wave-like property. Calculate the speed v of an electron having a de Broglie wavelength equal to the wavelength of the laser light in **(c)**.

v = ... $m\,s^{-1}$ [3]

[Total: 17]

END OF QUESTION PAPER

2822: Electrons and photons

1

(a)	Flow / movement of charge / charged particle(s) (Allow current = rate of flow of charge / current = rate of change of charge)	AW	B1
(b)	The charge (flowing past a point) in 1 s when current is 1 A (Allow 1C = 1A × 1s)		B1
(c)(i)	$I = \frac{\Delta Q}{\Delta t}$ / $I = \frac{340}{50}$ (Allow any subject - with or without Δ) 6.8 (A)		C1 A1
(c)(ii)	1. There is magnetic field (around the current-carrying strip(s) and hence a force)	AW	B1
	2. (Fleming's) left-hand rule		B1
	3. Towards A / To the left (Allow direction given on Fig.1.1)		B1
			[Total : 7]

2

(a)	current ∝ voltage / p.d. (for a metal conductor) [Allow $I \propto V$ because of **(b)**] as long as temperature remains constant / all physical conditions remain the same ($V = IR$ and R = constant scores 1/2) ($V = IR$ scores 0/2)	M1 A1
(b)(i)	(Semiconductor) diode	B1
(b)(ii)	Any five from: Resistance is given by $R = V/I$ (Allow the use of R for resistance in this question) The resistance is not constant / Diode is a non-ohmic (component) For negative value(s) (of V) resistance is infinite / (very) large (Allow a calculation) For V / value(s) less than 0.6 (V) the resistance is infinite / (very) large (Accept 0.62 V) For V / value(s) greater than 0.6 (V) the resistance is small / less For V / value(s) greater than 0.6 (V) the resistance decreases (as V increases) (Also scores mark above) Resistance correctly calculated at one point (Assume values are in ohms if unit is not given) Resistance correctly calculated at another point (Allow '*voltage increases the resistance decreases*' if there is no reference to 0.6 V and the second mark above is not scored)	B1 × 5
	QWC 'Spelling and grammar'	B1
		[Total : 9]

3

(a)	sum of current(s) into a point / junction = sum of current(s) out (from the point / junction) (-1 for omission of 'point' or 'sum' in the statement of the law) (Algebraic sum of current(s) at a point = 0 scores 2/2)	B2
(b)(i)	Thermistor	B1
(b)(ii)	I_1 = 51 (mA) I_2 = 9 (mA) I_3 = 29 (mA)	B1 B1 B1
		[Total : 6]

4			
(a)	$R = R_1 + R_2$ / $R = 200 + 120$ / $R = 320$		C1
	current $= \dfrac{8.0}{320}$		C1
	current $= 2.5 \times 10^{-2}$ (A)		A0
(b)	$V = 25 \times 10^{-3} \times 120$ / $V = \dfrac{120}{120+200} \times 8.0$		
	$V = 3.0$ (V)	(Possible ecf)	B1
(c)	p.d. across the 360 (Ω) resistor = p.d. across the 120 (Ω) resistor / There is no current between **A** and **B** / in the voltmeter (Allow '*A & B have same voltage*' - BOD)		B1
	The p.d. calculated across 360 Ω resistor is shown to be 3.0 V / The ratio of the resistances of the resistors is shown to be the same.		B1
			[Total : 5]
5			
(a)	Correct field direction		B1
	Correct field pattern (minimum of three lines)		B1
(b)(i)	length $= 2\pi \times 2.8 \times 10^{-2} \times 20$ / length $= 2\pi \times 2.8 \times 20$		M1
	length = 3.52 (m) ≈ 3.5 (m) / length ≈ 350 (cm)		A0
(b)(ii)	$R = \dfrac{\rho L}{A}$	(Allow any subject)	C1
	$R = \dfrac{4.9 \times 10^{-7} \times 3.5}{8.4 \times 10^{-7}}$		C1
	$R = 2.04 \approx 2.0$ (Ω)	(R =2.05 ≈ 2.1 Ω if 3.52 m is used)	A1
(c)(i)	$V = 6.0 \times 2.04$	(Possible ecf) (Allow initial current 5.7 A to 6.0 A)	C1
	$V = 12.2 \approx 12$ (V)	(Allow $V = 2.0 \times 2.04 \approx 4.1$ (V) 1 mark)	A1
(c)(ii)	$P = VI$	(Allow $P = I^2R$ or $P = V^2/R$)	C1
	$P = 12 \times 6.0$	(Possible ecf)	
	$P = 72$		A1
	watt / W / J s^{-1} / VA		B1

(c)(iii) Any <u>four</u> from: — B1 × 4

The temperature of the coil increases / the coil gets 'hotter' (Allow 'coil heats up')
The resistance / resistivity of coil increases (as its temperature increases)
The decrease in current is linked to $I = V/R$
More / frequent collisions of electrons and (vibrating) atoms / ions (as temperature / resistance increases)
The coil (eventually) reaches steady temperature / constant (higher) resistance

QWC 'Organisation' — B1

[Total : 16]

6

(a)	particle(-like) / particulate (nature) / photon ('behaviour')	B1
(b)(i)	A 'packet' of energy / radiation / A quantum of (EM) radiation / energy / light (Do <u>not</u> allow '*particle of light*')	B1
(b)(ii)	The <u>minimum</u> frequency (of the EM radiation) for emission of electrons / photoelectric effect	B1
(c)(i)	Visible (light)	B1
(c)(ii)	work function = $1.9 \times 1.6 \times 10^{-19}$ work function = 3.04×10^{-19} (J) $\approx 3.0 \times 10^{-19}$ (J)	M1 A0
(c)(iii)1.	$E = hf$ / $E = \dfrac{hc}{\lambda}$ $E = \dfrac{6.63\times10^{-34}\times 3.0\times10^{8}}{5.1\times10^{-7}}$ $E = 3.9 \times 10^{-19}$ (J)	C1 A1
2.	$hf = \phi + KE_{(max)}$ / $hf = \phi + \frac{1}{2}mv^2$ (Allow $E = \phi + \frac{1}{2}mv^2$ if E is qualified in **(c)(iii)1.**) $3.9 \times 10^{-19} = 3.0 \times 10^{-19} + KE_{(max)}$ / $3.9 \times 10^{-19} = 3.04 \times 10^{-19} + KE_{(max)}$ KE = 9.0×10^{-20} (J) / KE = 8.6×10^{-20} (J) (Possible ecf)	C1 C1 A1
(c)(iv)	No change (to maximum KE of electron) Each photon has same energy (but there are fewer photons)	B1 B1
(c)(v)	number of photons = $\dfrac{80\times10^{-3}}{3.9\times10^{-19}}$ ($\approx 2.05 \times 10^{17}$) (Possible ecf) number of electrons = $0.07 \times \dfrac{80\times10^{-3}}{3.9\times10^{-19}}$ number of electrons = 1.44×10^{16} (s^{-1}) $\approx 1.4 \times 10^{16}$ (s^{-1})	C1 A1
(d)	$\lambda = \dfrac{h}{mv}$ (Allow any subject) $5.1\times10^{-7} = \dfrac{6.63\times10^{-34}}{9.11\times10^{-31}\times v}$ $v = 1.43 \times 10^{3} \approx 1.4 \times 10^{3}$ (ms^{-1})	C1 C1 A1

[Total : 17]